

# DEVELOPMENT OF FIELD MEASUREMENT SYSTEMS FOR FLIGHT VEHICLE NOISE

*James C. Yu<sup>\*</sup>, Kenneth D. Wright<sup>\*\*</sup>, John S. Preisser<sup>#</sup>, and Michael A. Marcolini<sup>+</sup>*  
*NASA Langley Research Center, Hampton, Virginia 23681-2199 USA*

**Summary:** Field measurement of noise radiated from flight vehicles is an important element of aircraft noise research programs. At NASA Langley, a dedicated effort that spans over two decades was devoted to the development of acoustic measurement systems to support the NASA noise research programs. The new challenge for vehicle operational noise reduction through varying glide slope and flight path require noise measurement to be made over a very large area under the vehicle flight path. Such a challenge can be met through the digital remote system currently under final development at NASA Langley.

## INTRODUCTION

Field measurement of noise radiation from flight vehicles is a critical element of many aircraft noise research programs. Noise data gathered in the field can provide information not otherwise obtainable from laboratory and/or wind tunnel tests. Field data can be readily used to define the operational noise characteristics such as take-off, landing, and maneuver, to validate predictions, and to verify noise reduction concepts. Prior to the mid-70's, field measurements were usually made at few locations and requirements were not very demanding. Some of the field measurements were made with makeshift arrangements consisting of deployment of a few analog acoustic systems. In the late 70's and early 80's, field measurements of aircraft noise<sup>[1]</sup> were used to verify theoretical predictions and to correlate with measurements made in wind tunnels. Systematic development of analog field measurement systems with improved data analysis techniques were pursued by a few noise research establishments such as NASA Langley. In the late 80's and early 90's, however, the increased emphasis on noise reduction technology in the U.S. and the rest of the world for flight vehicles such as helicopters and tiltrotor<sup>[2]</sup>, jet transport, and future high-speed transport, placed strong demand for a comprehensive field noise database. Research use of field noise data included validation of theoretical and empirical predictions, evaluation of noise impact on communities<sup>[3-4]</sup>, vehicle detection and identification, and verification of operational noise reduction through optimized flight paths<sup>[5]</sup>. One of the NASA initiated programs that have placed very stringent requirements for field acoustic measurement is the Short-Haul Civil Tiltrotor Program. The research challenges presented by the Civil Tiltrotor program coupled with the military interest in acoustic detection became the primary drivers for a more sophisticated and operationally efficient field measurement system. In this paper we discuss the development of field acoustic measurement systems conducted at NASA Langley to support these research requirements. This development can be logically divided into four stages, the analog system, the advanced analog system, the digital system, and the digital remote system. The development strategy used was a high-level system integration

---

<sup>\*</sup> Division Chief, Experimental Testing Technology Division, Fellow ASA

<sup>\*\*</sup> Research Engineer, Experimental Testing Technology Division

<sup>#</sup> Branch Head, Aeroacoustics Branch, Fluid Mechanics and Acoustics Division, Member ASA

<sup>+</sup> Manager, Rotorcraft Research & Technology, Airframe Systems Program Office

with the research program. Figure 1 shows the history of this development effort and its integration with the evolving research requirements.

## **ANALOG AND ADVANCED ANALOG SYSTEMS**

The first serious field acoustic measurement at Langley was conducted to support the NASA Forward Flight Effects on Turbofan Noise Program (1978-1983). Ground measurements were made on the fan noise radiation from a JD-15D turbofan engine mounted on the starboard side of an OV-1 aircraft in flight. The objective of this field measurement effort was to compare static and wind tunnel engine fan noise measurements with those obtained in flight. The state-of-the-art B&K microphone systems were used. Twelve of such measurement systems were deployable with the support of an instrumentation vans. Linear microphone arrays where each microphones were mounted on very tall ground test stands (to minimize ground reflections) and protected by a windscreen were deployed parallel to the vehicle flight path. Signal boosters were used to increase the signal-to-noise ratio and to minimize the impedance loading by the long (500 feet or more) cables. An analog FM tape recorder installed in the van was used to record all flight data. The dynamic range of the overall system was about 45 dB. Factors that contributed to the low system dynamic range included the dynamic response of the microphone systems, the dynamic range of the recording device, and the cable's susceptibility to Radio Frequency Interference (RFI). The frequency response of the system was 10 kHz at 15 ips. Processing of data usually took weeks or months after field test was completed using NASA Langley's central data processing center, where analog-to-digital conversion of all recorded signals were first required. System reliability was limited due to cumbersome user interface, number of channels was limited by recording device, and cost of data storage was high because of recording tape cost. The initial analog systems developed for fan noise flight effects research, shown schematically in Figure 2, demonstrated the feasibility of accurate acoustic measurements of flight vehicles in the field. From 1985 to 1995, this original analog system was expanded to 24 channels supported by two analog data vans with improved instrumentation and self-contained data processing capabilities in the vans.

## **DIGITAL SYSTEM - WORKHORSE OF THE 90**

From 1985 to 1994, field measurement of noise was driven by two separate research requirements: the acoustic detection for the military helicopters and the noise prediction, reduction, and community impact of civil rotorcraft including the tiltrotor. While these two requirements placed different challenges to the acoustic research, they required similar measurement system development. Large number of measurement channels, improved dynamic range, adequate frequency response, efficient data recording, storage, and processing were needed. While the advanced analog system was continuously exploited for field measurements, a new effort aimed at the development of a digital system was initiated. With the rapid advances of digital electronics, heavy use was made of digital signal processing technology. One of the key features of the digital system developed over this period was a 16 bit analog to digital (ATD) conversion performed at the microphone location

and stored in digital format on 8 mm tapes. This ATD system provided several key advantages including increased dynamic range of 90 dB, insusceptibility to RFI, ability of some preliminary processing of the data in the field at the end of each test day, and significant reduction of tape storage cost (a factor of 10 over analog tapes). Sample rate of system was limited to 25000 sample/sec (frequency response ~ 12 kHz) for ten channels due to sustained transfer rate of 8 m storage system. Although the system met the research measurement requirements, it lacked an ease for upgrades because it was designed and built in-house due to a lack of availability of the commercial-off-the-shelf (COTS) systems. This practice of developing system components in-house also made the needed upgrades costly and time consuming. The user interface of the digital system was much improved over the early analog system, but still lacked flexibility for handling variations in testing that was desired. Current measurement capability with the digital system includes 3 digital data vans supporting a total of 30 microphone channels. With the successful deployment of the digital system, arrays of over 15,000 square feet in measurement area are now possible, but it still requires intensive effort to set up cables for transmitting data from microphone sites to acquisition vans. Figure 3 shows schematically the digital system configuration of today.

### **DIGITAL REMOTE SYSTEM - CURRENT DEVELOPMENT**

Since 1995, the need to acquire field rotorcraft noise data for defining the noise sources, validation of noise prediction algorithms, and evaluation of source noise reduction still remains and the digital system was continuously used to support the field noise measurement, however, NASA's noise research had a new challenge. This is the need to evaluate tiltrotor community noise control through flight operations as part of the Short-Haul Civil Tiltrotor Program. With this need, the proven linear array approach must be modified to allow noise measurement over a substantially large area under the flight path. The area to be covered is typically 5 miles by 5 miles. This area coverage requirement made the usage of cables to connect measuring microphones to the data vans an unattractive option and prompted the development of Radio Frequency (RF) transmission to control and monitor data from microphone locations. The digital remote system, still under final stage of development, met area coverage requirement. In this effort, systems engineering approach was used to manage and integrate the development process. Concurrent engineering and close coordination of individual activity of the development team have been emphasized throughout the life cycle of the system. LabView based user interface allowed tremendous flexibility in customizing the system for any configurations. Modular COTS components were adapted for use in the system to keep design and fabrication simple and costs down. A clear path for future upgrades was provided by using standards such as tcp/ip. The system used Intel based processors, and GPS timecode and position. The hardware chip count was reduced through the use of Erasable Programmable Logic Devices (EPLD's) where unique electronic design was required. This allowed reduced design time and eliminated the need for rebuilding printed circuit boards (EPLD's can be reprogrammed with upgraded circuitry). The system allows for quick look of data in acquisition vans to verify signal integrity between data runs. Acquisition rate is no longer limited by storage device because data is stored at each microphone site and transferred to permanent storage medium at end of test day. Similarly data reduction can now be performed on-site in the vans to gain a full grasp of the test data to

make effective tactical decisions for the test program. Figure 4 illustrates the system configuration in the final stage. This system will be deployed the summer of 1999.

## REFERENCESS

1. Preisser, J.S. and Chestnutt, D. "Flight Effect on Fan Noise with Static and Wind Tunnel Comparison", J. Aircraft, Vol. 21, No. 7, July 1984, pp. 452-461.
2. Lucas, M.J., and Marcolini, M. A., "Rotorcraft Noise Model". Proceedings of the American Helicopter Society Technical Specialists' Meeting for Rotorcraft Acoustics and Aerodynamics, Williamsburg, VA. October 1997.
3. Mueller, A.W., and Wilson, M.R., "The Effect of Linear Microphone Array Changes on Computed Sound Exposure Level Footprints", SAE International Noise and Vibration Conference and Exposition, Traverse City, MI, May 1997.
4. Wilson, M.R., Mueller, A.W., and Rutledge, C.K., "A New Technique for Estimating Ground Footprint Acoustics for Rotorcraft Using Measured Sound Fields",
5. Connor, D.A., Marcolini, M. A., Edwards, B. D., and Briger, J.T., "XV-15 Tiltrotor Low Noise Terminal Area Operations", AHS 53<sup>rd</sup> Annual Forum and Technology Display, Virginia Beach, VA April, 1997.

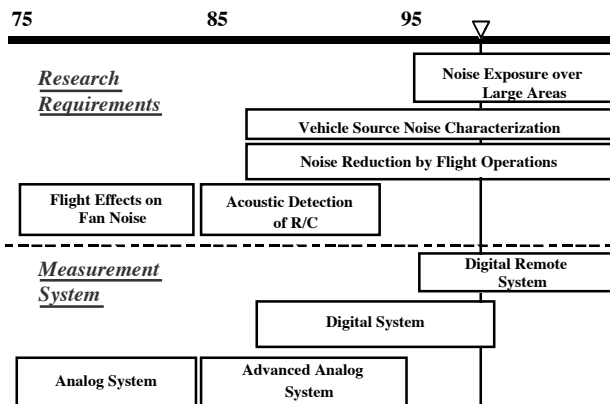


Figure 1. Development History and Strategy

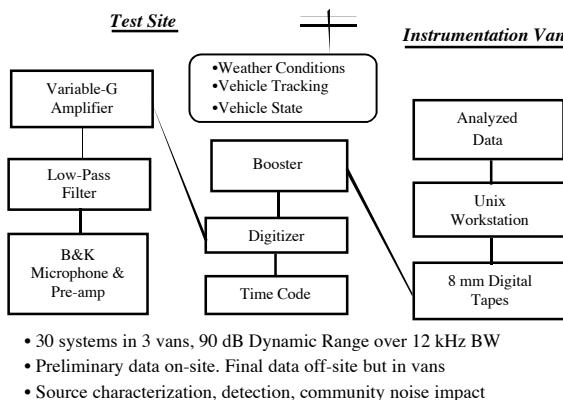


Figure 3. Schematics of the Digital System

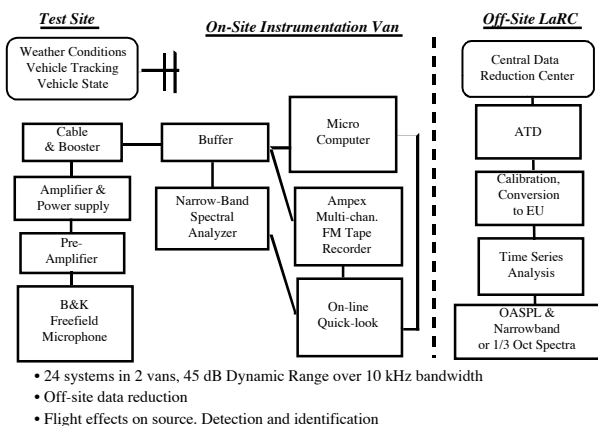


Figure 2. Schematics of the Analog System

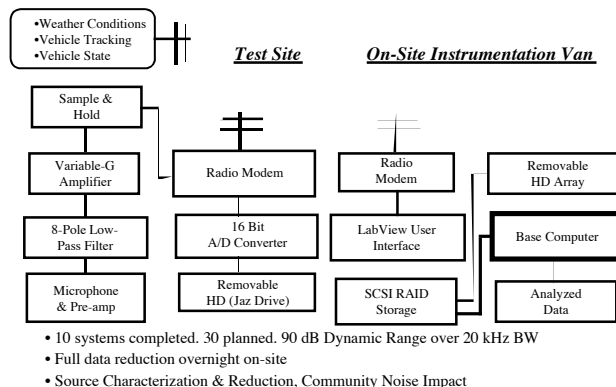


Figure 4. Schematics of the Digital Remote System